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(54) Information signal recording method

(57) The present invention provides a method of recording and reproducing information signals of binary digital signal train using an information signal recording medium formed with circular information signal tracks by scrambling and de-scrambling the information signals with scrambling signals having cyclic codes, said tracks being divided into a plurality of sectors each having a sector address characterised in that the method comprises the steps of:
generating a plurality of initial values according to the sector addresses;
generating a scrambling signal based on each generated initial value; and
scrambling the information signals, and, in the case of reproduction,
de-scrambling scrambled information signals read from said recording medium, in each sector with one of said generated scrambling signals, each said scrambling signal being used for a predetermined plurality of sequential sectors,
wherein a starting point in said cyclic codes of the scrambling signal used for the signals in each said predetermined plurality of sequential sectors is offset by a predetermined offset value from the starting point of the scrambling signal used for the signals in the immediately preceding predetermined plurality of sequential sectors, sectors in adjacent portions of said signal tracks being scrambled using different scrambling signals.

The information signal recording method can remove the correlation between adjacent tracks and thereby enables a stable tracking control.

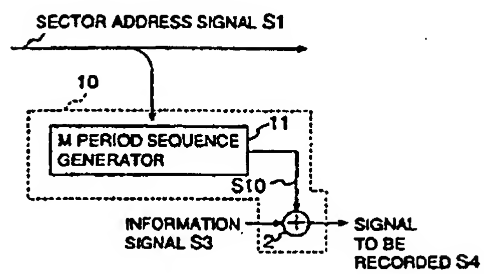

FIG.1

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Description

[0001] The present application is divided from European Patent Application 94308785.8 (serial no. 0655739) filed 29 November 1994, the "parent case".

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present invention relates to a method of recording and reproducing information signals using an information signal recording medium formed with a plurality of circular tracks, and more specifically to a method of recording and reproducing information signals scrambled with scrambling signals.

Description of the Prior Art

[0003] In general, in an optical disk such as a compact disk (CD), digital signals are recorded by forming concave and convex portions (referred to as pit and land portions) along tracks formed on the disk, and the light reflected from the pit and land portions is received by a quadrant optical sensor housed in an optical head, and further converted into electric signals to read information signals from the optical disk.

[0004] For focusing the detection light onto the optical disk, an objective lens of the optical system housed in a pickup is so controlled as to follow the surface deflection of the disk in accordance with astigmatic method, for instance. In addition, for tracking to eccentric tracks, the pickup is so controlled as to follow the tracks in accordance with three-beam method, push-pull method, heterodyne method, etc.

[0005] In the focusing and tracking control, the respective output signals of the double- or quadrant-divided optical sensor are calculated to obtain a focusing control signal and a tracking control signal for servo-controlling.

[0006] A laser beam emitted by the pickup produces a phase difference between the beam reflected from the pit portion and the beam reflected from the land portion, so that it is possible to obtain reproduced signals on the basis of the difference in reflected light intensity caused by the interference effect and then incident upon the optical sensor. In the case of a compact disk, data are recorded by forming pit and land pattern on the basis of EFM (eight to fourteen modulation) signals. Therefore, the recorded data can be reproduced by binarizing the reproduced signals modulated on the basis of the light intensity change along the pit and the land portions, and further demodulated into 10 digital signals.

[0007] In the signal recording system, two system, that is, a CAV (constant angular velocity) system in which the disk angular velocity is kept constant and CLV (constant linear velocity) system in which the track linear velocity is kept constant are so far known. In the case of the CAV system, the number of sectors of each track is equal to each other, and all the tracks are so formed that the sector heads of all the tracks are perfectly arranged on the radial lines extending from the disk center.

[0008] Further, in the case of the CLV system, since the track liner velocity is constant, although the sector heads of all the tracks do not match each other on the disk, there exists some cases where the sector heads of a part of the adjacent tracks are arranged along on the same radial line extending from the disk center.

[0009] Under these circumstances, in the case where a great quantity of the information signals of the same contents such as music intermissions, no-music sections, no-image sections, etc. are recorded for instance when music or image information signals are recorded, the recorded information signals are scrambled with scrambling signals in general in order to prevent the signals of the same pit and land shape or arrangement from being recorded in the adjacent tracks.

[0010] The scramble procedure as described above is adopted to prevent the synchronizing signal for synchronizing the sector heads of information signals from being generated in the recorded data as pseudo-synchronizing signal, that is, to improve the DSV (digital sum variation) controllability of the EFM signal. That is, the information signals and scrambling signals referred to as M (maximum) period sequence are scrambled with each other, and ten the scrambled signals are recorded as the information signals. Here, the M period sequence used for 'scrambling procedure is cyclic codes represented by $(2^x - 1)$ units of 0 or 1.

[0011] For instance, the prior art scrambling means adopted in the conventional CD-ROM outputs the M period sequence of cyclic codes of $(12^{15} - 1 = 32767)$ represented by 0 or 1. Further, information signals are scrambled with the cyclic codes by using the same initial value (code) for each sector.

[0012] US-A- 5014274 discloses apparatus for recording digital information on a recording medium such as a magnetic tape and reproducing the recorded information. In particular, as described, the document describes a code-error correcting device which comprises a circuit for generating a pseudo-random or quasi-random function and which computes the exclusive-or function of digital information and an output of the circuit for generating the pseudo-random func-

tion. The computed exclusive-or value is supplied to a digital modulator as an input. In this arrangement an initial value for generating the pseudo-random function is the address information or data-block information related to the address information of the digital information.

[0013] The above mentioned document also describes a further code-error correcting device which comprises a circuit for generating the same pseudo-random function and which calculates the exclusive-or of digital demodulation information and an output of the circuit generating the pseudo-random function, and in order to derive the original data information. Once again, the initial value for generating the pseudo-random function is the address information of data block information related to the address information, now of the demodulation data block information.

[0014] In this arrangement the de-scrambling of the scrambled signal is effective when the pseudo-random function produces the same sequence in the demodulation as in the modulation. In particular the described demodulator comprises an M sequence generator which is the same as the M sequence generator in the described modulator and these are supplied with the same initial values.

[0015] A similar type of arrangement is described in JP-A-62/95704. This document describes a signal recording and reproducing device in which a main signal is modulated with an M series signal so as to form a recording signal, a reproduced version of which is demodulated using the M-series signal.

[0016] In the present tendency of the optical disk, the disk capacity and disk density are both increased more and more. In the prior art scrambling means as described above, however, when the information signals of the same contents are recorded at the same positions at which the sector heads are arranged in the radial lines extending from the disk center, since the shape at the pit portion matches the shape at the land portion, correlation between both the portions increases, with the result that an amplitude of the tracking error signal is reduced and thereby the S/N (signal to noise) ratio decreases, thus causing a problem in that the tracking control cannot be executed stably.

SUMMARY OF THE INVENTION

[0017] The present invention provides a method of recording and reproducing information signals of binary digital signal train using an information signal recording medium formed with circular information signal tracks by scrambling and de-scrambling the information signals with scrambling signals having cyclic codes, said tracks being divided into a plurality of sectors each having a sector address characterised in that the method comprises the steps of:

generating a plurality of initial values according to the sector addresses;
generating a scrambling signal based on each generated initial value; and
scrambling the information signals, and, in the case of reproduction, de-scrambling scrambled information signals read from said recording medium, in each sector with one of said generated scrambling signals, each said scrambling signal being used for a predetermined plurality of sequential sectors,
wherein a starting point in said cyclic codes of the scrambling signal used for the signals in each said predetermined plurality of sequential sectors is offset by a predetermined offset value from the staffing point of the scrambling signal used for the signals in the immediately preceding predetermined plurality of sequential sectors, sectors in adjacent portions of said signal tracks being scrambled using different scrambling signals.

[0018] The present invention also provides a method of recording and reproducing information signals of binary digital signal train using an information signal recording medium formed with circular information signal tracks divided into a plurality of sectors each having a sector address by scrambling and de-scrambling the information signals with scrambling signals having cyclic codes, the method comprising the steps of:

generating a first initial value based on the sector address, the first initial value being used over first sequential sectors of a predetermined number of sectors;
generating a second initial value based on the sector address, the second initial value being used over second sequential sectors of the predetermined number of sectors;
generating a first scrambling signal based on the first initial value;
generating a second scrambling signal based on the second value; and
scrambling the information signals, and, in the case of reproduction, de-scrambling scrambled information signals read from said recording medium, per sector with repeated use of the first scrambling signal that starts at the first initial value with respect to each sector of the first sequential sectors and with repeated use of the second scrambling signal that starts at the second initial value with respect to each sector of the second sequential sectors,
wherein a staffing point of the second scrambling signal corresponding to the second initial value is offset by a predetermined offset value from another starting point of the first scrambling signal corresponding to the first initial value.

[0019] The present invention further provides a method of reproducing original information signals by de-scrambling scrambled information signals of binary digital signal train read from an information signal recording medium formed with circular information signal tracks, the scrambled information signals having been scrambled with scrambling signals having cyclic codes, said tracks being divided into a plurality of sectors each having a sector address characterised in that the method comprises the steps of:

generating a plurality of initial values according to the sector addresses;
generating a scrambling signal based on each generated initial value; and
de-scrambling the scrambled information signals in each sector with one of said generated scrambling signals, each said scrambling signal being used to de-scramble a predetermined plurality of sequential sectors,
wherein a starting point in said cyclic codes of the scrambling signal used to de-scramble the signals in each said predetermined plurality of sequential sectors is offset by a predetermined offset value from the starting point of the scrambling signal used to de-scramble the signals in the immediately preceding predetermined plurality of sequential sectors, sectors in adjacent portions of said signal tracks having been scrambled using different scrambling signals.

[0020] The present invention additionally provides a method of reproducing original information signals by de-scrambling scrambled information signals of binary digital signal train read from an information signal recording medium formed with circular information signal tracks divided into a plurality of sectors having sector addresses, the scrambled information signals having been scrambled with scrambling signals having cyclic codes, the method comprising the steps of:

generating a first initial value based on the sector address, the first initial value being used over first sequential sectors of a predetermined number of sectors;
generating a second initial value based on the sector address, the second initial value being used over second sequential sectors of the predetermined number of sectors;
generating a first scrambling signal based on the first initial value;
generating a second scrambling signal based on the second value; and
de-scrambling the scrambled information signals per sector with repeated use of the first scrambling signal that starts at the first initial value with respect to each sector of the first sequential sectors and with repeated use of the second scrambling signal that starts at the second initial value with respect to each sector of the second sequential sectors,
wherein a starting point of the second scrambling signal corresponding to the second initial value is offset by a predetermined offset value from another starting point of the first scrambling signal corresponding to the first initial value.

[0021] In the above methods, the information signals are preferably scrambled and said read scrambled information signals are de-scrambled by obtaining exclusive OR of the signals and the cyclic codes composed of $(2^x - 1)$ units of binary numbers;

and further a degree x of the cyclic codes is determined as follows:

$$x > \log_2 \{8 \times B_{sect} \times (1 + S_{max} / S_{min}) + 1\}$$

where B_{sect} denotes the number of bytes of the information signals recorded in one sector of the recording medium, S_{max} denotes the number of sectors included in an outermost circumferential track of the recording medium, and S_{min} denotes the number of sectors included in an innermost circumferential track of the recording medium.

[0022] Correspondingly, the present invention provides apparatus for recording and reproducing information signals of binary digital signal train using an information signal recording medium formed with circular information signals implementing the methods defined above.
[0023] In the present invention therefore the information signals are recorded such that correlation between the adjacent tracks is removed, when scrambled information signals of binary digital signals are recorded on an information recording medium formed with circular information tracks.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024]

Fig. 1 is a block diagram showing the scrambling means of a first information signal recording method according to the invention claimed in the parent case;
Figs. 2A to 2C are illustrations for assistance in explaining the relationship between the scramble procedure and the M period sequence;
Figs. 3A and 3B are illustrations showing the linear scramble patterns of the outermost circumferential track and the succeeding circumferential track in the first information signal recording method according to the arrangement described with reference to Fig. 1;
Fig. 4A is a block diagram showing the scrambling means of a second information signal recording method according to the invention claimed in the parent case;
Fig. 4B is an illustration for assistance in explaining the M period sequence generated by the scrambling means shown in Fig. 4A;
Figs. 5A and 5B are illustrations showing the linear scramble patterns of the innermost circumferential track and the succeeding circumferential track in the second information signal recording method according to the arrangement described with reference to Fig. 4A; and
Figs. 6A to 6C are illustrations showing the linear scramble patterns of the innermost circumferential track and the outermost circumferential track and the tracks adjacent thereto respectively in an embodiment of the present invention, which embodiment is a modification of the second information signal recording method according to the arrangement described with reference to Fig. 4A.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0025] An embodiment of the method of recording information signals according to the present invention will be described hereinbelow after a description of certain methods which are the subject of claims in the parent case, all with reference to the attached drawings.

[0026] In Fig. 1, image or audio digital information signals S3 (which have been error-corrected and interleaved) are scrambled by a scrambled signal generating section 10, and then recorded on a compact disk as the scrambled information signals S4.

[0027] The scrambled signal generating section 10 shown in Fig. 1 is composed of an M (maximum) period sequence generator 1 (constructed by shift registers) for generating M period sequence (scrambling signals) S10, and an adder section 2 for obtaining an exclusive OR of the M period sequence S10 and the information signals S3, and outputting the scrambled information signals as information signals S4 to be recorded. In more detail, sector address signals S1 separated from the information signals S3 are inputted to the M period sequence generator 1. Then, the shift registers (not shown) of the M period sequence generator 1 are reset to start generating the scrambling signals S10. The information signals S3 are scrambled with the scrambling signals S10 through the adder 2, and then outputted as the scrambled information signals S4 actually recorded on a recording medium.

[0028] Figs. 2A to 2C show the relationship between the scramble procedure and the M period sequence. As shown in Fig. 2A, in the recording region of an information signal recording medium 5 such as a disk, a T(n)-th track and a T(n+1)-th track are formed concentrically or spirally. In these drawings, a CLV (constant liner velocity) recording system is shown, in which the sectors of the respective tracks start from the same radial line L extending from the disk center O. Fig. 2B shows the information signals recorded in two adjacent tracks in the CLV recording system are rewritten in straight lines. Further, Fig. 2C shows the arrangement of the recorded signals in this CLV recording system.

[0029] Here, the method of deciding the degree and the initial value of the M period sequence used by the scrambled signal generating section 10 will be described. In the case of the recording system of the CLV system, the constants related to the recorded disk are previously given as follows:

- S_{min}: the number of sectors included in the innermost circumferential track
- S_{max}: the number of sectors included in the outermost circumferential track
- D_w: Offset width (unit: sector) between the initial value of an M period sequence and that of a next M period sequence ($0 < D_w$)
- C_{ycle}: the maximum number of sectors expressed by the cyclic period (2_x - 1) of an M period sequence
- B_{sect}: the number of information signal bytes contained in one sector

[0030] Figs. 3A and 3B show the positional relationship of the information signals recorded through the scramble procedure (after having been scrambled by the scrambled signal generating section 10 of Fig. 1) at the outermost cir-

cumferential track and the circumferential track adjacent to the outermost track. In the M period sequence shown in Fig. 3A, the scrambling signals (whose cyclic period is longer than the time length of the information signal quantity recorded at the outermost circumferential track) and the information signals are recorded at the outermost circumferential track in such a way as to one-to-one (1 : 1) correspond to each other.

[0031] In the arrangement of the recorded signals shown in Fig 3B, the information signals recorded on the two adjacent tracks are rewritten linearly beginning from the same radial line L extending from the disk center O shown in Fig. 2A, in spite of the fact that the recorded signals are actually recorded concentrically or spirally beginning from the disk center O as shown in Fig. 2A.

[0032] From the nature of the M period sequence, even if a great quantity of the same information signals are recorded, since different scrambled signals can be recorded in the information signal recording range of the outermost circumferential track, it is possible to record different signals at the adjacent tracks on the radial line L extending from the disk center O at all the tracks from the innermost circumferential track to the outermost circumferential tack.

[0033] Under the considerations as described above, the conditions of the degree of the M period sequence to be used are as follows:

$$S_{max} < C_{ycle} \tag{1}$$

[0034] Here, C_{ycle} can be expressed in unit of sector as follows:

$$C_{ycle} = (2^x - 1) / (8 \times B_{sect}) \tag{2}$$

[0035] Accordingly, the degree x of the required M period sequence can be obtained by the following formulae (3), (4) and (5) as expressed below:

$$S_{max} < (2^x - 1) / (8 \times B_{sect}) \tag{3}$$

$$2^x > 8 \times B_{sect} \times S_{max} + 1 \tag{4}$$

$$x > \log_2 (8 \times B_{sect} \times S_{max} + 1) \tag{5}$$

[0036] Therefore, when the information signals S3 are scrambled by the scrambling signals S10 having a cyclic period $(2^x - 1)$ of the M period sequence determined by the degree obtained by the above formula (5), it is possible to obtain the scrambled recorded signals S4 for providing a stable tracking.

[0037] For instance, in the case of the CD-ROM, since the quantity of information signals contained in one sector is 2352 bytes, and the quantity of information signals contained in the outermost circumferential track is about 22 sectors, when the degree X is calculated in accordance with the formula (5), as far as the M period sequence of 19 degrees or more is used, it is possible to record different signals at the adjacent tracks on the radial line extending from the disk center all over the tracks from the innermost to the outermost circumferential tracks.

[0038] As described above, since the period at which the scrambling signals S10 make a round is determined to be longer than the time length of the information signal quantity recorded at the maximum capacity track (i.e., the outermost circumferential track), it is possible to remove the correlation between the adjacent tracks.

[0039] Therefore, even if the track pitch is narrowed on the recording medium for higher recording density, it is possible to execute a stable tracking control.

[0040] Fig. 4A shows the scrambling means for executing a second information signal recording method.

[0041] As shown in Fig. 4A, the address of a scrambled signal generating section 50 is designated on the basis of sector address signals S1 separated by the information signals S3. The section 50 is composed of an initial value memory 20 (e.g., ROM) for generating previously stored initial values, an M period sequence generator 30 (composed of shift registers) for generating the scrambling signals S20 of the M period sequence on the basis of the output of the memory 20, and an adder 40 for adding (exclusive OR) the information signals S3 of digital signal train and the scrambling signals S20 to form scrambled signals S40 to be recorded. In this second embodiment, as shown in Fig. 4B, a predetermined length D_w is offset between the initial value of the M period sequence and the initial value of the succeeding M period sequence.

[0042] Figs. 5A and 5B show the positional relationship of the information signals recorded through the scramble procedure at the innermost circumferential track and the circumferential track adjacent to the innermost track after having been scrambled by the scrambled signal generating section 50 shown in Fig. 4A.

[0043] In the M period sequence shown in Fig. 5A, the cyclic period of the scrambling signals is assumed to be longer than the time length of the number of information bits contained in at least two sectors.

[0044] In the M period sequence as shown in Fig. 5A, the scramble procedure is executed by offsetting the initial

value of the M period sequence at the present sector by an offset value D_w from the initial value of the preceding sector.

[0045] In the arrangement of the recorded signals shown in Fig 5B, the information signals recorded on the two adjacent tracks are rewritten linearly beginning from the radial line L extending from the disk center O shown in Fig. 2A, in spite of the fact that the recorded signals are actually recorded concentrically or spirally beginning from the disk center O as shown in Fig. 2A.

[0046] In Fig. 5, the problem arises with respect to the correlation between signals recorded at the first sector 1 of the innermost circumference and signals recorded at the sectors (n+1) and (n+2) of the adjacent circumferential track (the innermost + 1) at the same radial position of the recording medium.

[0047] In Fig. 5B, when the scrambled information signals including the scrambling signals are recorded at the adjacent sectors of the problem, in the case of the same information signals, the same scrambled signals are recorded in the sector 1 of the innermost circumferential track and the sectors (n + 1) and (n + 2) of the succeeding track.

[0048] Therefore, in the case where the information signals for the sector corresponding to the innermost circumference S_{min} can be recorded, it is necessary to execute the scramble procedure of the sector (S_{min} + 1) by use of an initial value of the M period sequence offset from the M period sequence used for the sector 1 by a value more than the M period sequence code used for one sector.

[0049] That is, the above-mentioned content can be expressed as follows:

$$S_{min} \times D_w > 1 \tag{6}$$

[0050] Here, the outermost circumferential track of the disk will be taken into account.

[0051] In practice, the outermost circumferential track and the adjacent (outermost circumference - 1) track must be considered. Here, however, the assumption is made that there exists another adjacent (outermost circumference + 1) track.

[0052] Since the object that the same scramble pattern must not be generated between the two adjacent tracks is the same, the method of determining the constants will be explained.

[0053] When the degree x of the M period sequence is decided on the basis of the information signal bits contained in the outermost circumferential track, since the same scramble pattern as that used at the outermost circumference is to be recorded at the (outermost + 1) circumferential track, it is necessary to select the M period sequence having a cyclic period longer than that which can circulates the sectors obtained by adding the number of sectors ($1/D_w$) to the number of sectors contained in the outermost circumferential track, until a part of the M period sequence used at the first sector of the outermost circumferential track will not be used again. Therefore, the following formula must be satisfied:

$$(S_{max} + 1/D_w) \times D_w < C_{ycle} \tag{7}$$

[0054] Therefore, on the basis of the above formulae (6) and (7), the following formula can be obtained:

$$1/S_{min} < D_w < (C_{ycle} - 1)/S_{max} \tag{8}$$

[0055] Here, S_{min} and S_{max} can be decided on the basis of the disk to which information signals are to be recorded. Accordingly, when the C_{ycle} is rewritten in unit of sector, the formula (8) can be expressed as

$$C_{ycle} = (2^x - 1)/(8 \times B_{sect}) \tag{9}$$

[0056] Therefore, it is possible to obtain the degree x of the M period sequence on the basis of the right and left sides of the formula (8) and in accordance with the following formulae (10), (11) and (12) as follows:

$$1/S_{min} < [(2^x - 1)/(8 \times B_{sect}) - 1]/S_{max} \tag{10}$$

$$2x > 8 \times B_{sect} \cdot (1 + S_{max}/S_{min}) + 1 \tag{11}$$

$$X > \log_2 [8 \times B_{sect} \times (1 + S_{max}/S_{min}) + 1] \tag{12}$$

[0057] The right and left sides of the formula (7) are both constants, so that it is possible to decide the offset width D_w.

[0058] For instance, in the CD-ROM, since the information signal quantity contained in one sector is 2352 bytes and the numbers of sectors contained in the outermost and innermost circumferential tracks are about 22 and 9 sectors respectively, when the degree x is calculated in accordance with the formula (12), it is understood that the M period

sequence of 16 degrees or more must be used. That is, when the scrambling signals of 16 degrees or more are used, it is possible to record different signals at the adjacent tracks on the same radial lines L extending from the disk center O all over the tracks from the innermost and outermost circumferential tracks.

[0059] Here, when the results of this second method are compared with those of the first method, in the case of the first method, the M period sequence of 19 degrees is necessary to remove the correlation between the adjacent tracks. In the case of the second method, on the other hand, the same effect can be obtained by use of the M period sequence of 16 degrees.

[0060] As described above, it is possible to remove the correlation between the adjacent tracks by use of a part of the scrambling signals repeatedly under overlapped conditions, so that it is possible to execute the tracking control stably even if the track pitch is reduced.

[0061] A modification of the second method above will be described and is an embodiment of the present invention. In this modification, the scrambled signal generating section 50 shown in Fig. 4A is used. Figs. 6A and 6B show the positional relationship of the information signals recorded through the recording procedure (after having been scrambled by the section 50) of this modification (which is different from the second method) at the innermost and outermost circumferential tracks of the recording medium.

[0062] In the M period sequence shown in Fig. 6A, assuming that the cyclic period of the scrambling signals is longer than the number of information signal bits contained in at least two sectors, the initial value is so determined that the same pattern can be included only within a range of (1 - D_w) in the succeeding scramble pattern.

[0063] In the arrangement of the recorded signals shown in Figs. 6B and 6C, the information signals recorded on the two adjacent tracks are rewritten linearly beginning from the radial line L extending from the disk center O shown in Fig. 2A, in spite of the fact that the recorded signals are actually recorded concentrically or spirally beginning from the disk center O as shown in Fig. 2A.

[0064] The innermost circumferential track is taken into account.

[0065] In the same way as with the case of the second method, the problem arises with respect to the correlation between the first signal recorded in the sector 1 of the innermost circumferential tack and the signals recorded within the range at the adjacent track between the two radial lines L obtained by extending from the disk center O to the first and last of the sector 1 of the innermost circumferential track.

[0066] In Fig. 6B, the scramble procedure to the sectors (n+1) and after is executed by use of the initial value of the scrambling signals offset more than the information signal quantity contained in one sector from the initial value of the scrambling signals used for the sector 1.

[0067] Here, if the number of times that one scrambling signal is repeated continuously is denoted by M_{loop}, the formula (13) can be expressed as:

$$(S_{min} / M_{loop}) X D_w > 1 \tag{13}$$

[0068] Here, the outermost circumferential tack of the disk will be taken into account.

[0069] In practice, the outermost circumferential track and the adjacent (outermost circumference - 1) track must be considered. Here, however, the assumption is made that there exists another adjacent (outermost circumference + 1) track.

[0070] Since the object that the same scramble pattern must not be generated between the two adjacent tracks is the same, here, the method of deciding the constants will be explained.

[0071] When the degree of the M period sequence is decided on the basis of the information signal bits contained in the outermost circumferential track, at the (outermost circumference + 1) track since the scrambled signals quite the same as those used for the outermost circumferential track are recorded, at the (outermost circumference + 1) track it is necessary to use the scrambling signal B_{sect} or more before the scrambling signal used at the first of the outermost circumferential track, as the scrambling signal used at the sector positioned on the same radial line of the first of the outermost circumferential track. Therefore, the following formula can be obtained:

$$[(S_{max} / M_{loop}) + 1 / D_x) X D_w < C_{ycle} \tag{14}$$

[0072] Therefore, on the basis of the above formulae (13) and (14), the following formula can be obtained:

$$M_{loop} / S_{min} < D_w < (C_{ycle} - 1) X M_{loop} / S_{max} \tag{15}$$

[0073] Here, S_{min} and S_{max} can be both decided on the basis of the disk to which information signals are to be recorded. Accordingly, the C_{ycle} of the formula (16) can be expressed in unit of sector as follows:

$$C_{ycle} = (2^x - 1) / (8 X B_{sect}) \tag{16}$$

[0074] Therefore, it is possible to obtain the degree x of the M period sequence on the basis of the right and left sides of the formula (15) and in accordance with the following formulae (17), (18) and (19) as follows:

$$M_{loop} / S_{min} < [(2^{x} - 1) / (8 \times B_{sect}) - 1] \cdot M_{loop} / S_{max} \quad (17)$$

$$2^{x} > 8 \times B_{sect} \times (1 + S_{max} / S_{min}) + 1 \quad (18)$$

$$X > \log_2 [8 \times B_{sect} \times (1 + S_{max} / S_{min}) + 1] \quad (19)$$

[0075] The formula (19) is the same as that (12) of the second embodiment, so that it is possible to obtain the same result.

[0076] Here, when the results of this embodiment are compared with those of the first method above, in the case of the first method, the M period sequence of 19 degrees is necessary to remove the correlation between the adjacent tracks. In the case of this embodiment, on the other hand, the same effect can be obtained by use of the M period sequence of 16 degrees.

[0077] Further, since the same scrambling signals can be used repeatedly, there exists another effect such that the number of initial values to be recorded on the initial value storing section 26 shown in Fig. 4A can be reduced as compared with that of the second method above.

[0078] In the above-mentioned embodiment, although the present invention has been explained by taking the case where information signals are recorded in the CLV system, it is of course possible to adopt the present invention when the information signals are recorded in the CAV system.

[0079] As described above, the information signal recording method according to the present invention provides the following excellent effects:

[0080] In the invention the correlation between the adjacent tracks is removed.

[0081] Therefore, it is possible to execute a stable tracking control even if the track pitch is reduced on the recording medium for higher recording density.

[0082] Further, since a part of the scrambling signals is used repeatedly, it is possible to decrease the number of initial values of the scrambling signals to be stored in the memory section. Further, since the degrees of the scrambling signals (M period sequence) can be reduced, it is possible to simplify the scrambled signal generating section to that extent.

Claims

1. A method of recording and reproducing information signals of binary digital signal tram using an information signal recording medium formed with circular information signal tacks divided into a plurality of sectors each having a sector address by scrambling and de-scrambling the information signals with scrambling signals having cyclic codes, the method comprising the steps of

   generating a plurality of initial values according to the sector addresses;
   generating a scrambling signal based on each generated initial value; and
   scrambling the information signals, and, in the case of reproduction, de-scrambling scrambled information signals read from said recording medium, in each sector with one of said generated scrambling signals, each said scrambling signal being used for a predetermined plurality of sequential sectors,
   wherein a starting point in said cyclic codes of the scrambling signal used for the signals in each said predetermined plurality of sequential sectors is offset by a predetermined offset value from the starting point of the scrambling signal used for the signals in the immediately preceding predetermined plurality of sequential sectors, sectors in adjacent portions of said signal tracks being scrambled using different scrambling signals.

2. A method of recording and reproducing information signals of binary digital signal train using an information signal recording medium formed with circular information signal tracks divided into a plurality of sectors each having a sector address by scrambling and de-scrambling the information signals with scrambling signals having cyclic codes, the method comprising the steps of:

   generating a first initial value based on the sector address, the first initial value being used over first sequential sectors of a predetermined number of sectors;
   generating a second initial value based on the sector address, the second initial value being used over second sequential sectors of the predetermined number of sectors;
   generating a first scrambling signal based on the first initial value;

generating a second scrambling signal based on the second value; and

scrambling the information signals, and, in the case of reproduction, de-scrambling scrambled information signals read from said recording medium, per sector with repeated use of the first scrambling signal that starts at the first initial value with respect to each sector of the first sequential sectors and with repeated use of the second scrambling signal that starts at the second initial value with respect to each sector of the second sequential sectors,

wherein a starting point of the second scrambling signal corresponding to the second initial value is offset by a predetermined offset value from another starting point of the first scrambling signal corresponding to the first initial value.

3. The method of Claim 1 or 2, wherein the information signals are scrambled and said read scrambled information signals are de-scrambled by obtaining exclusive OR of the signals and the cyclic codes composed of $(2^x - 1)$ units of binary numbers;

and further a degree x of the cyclic codes is determined as follows:

$$x > \log_2 \{8 \times B_{sect} \times (1 + S_{max} / S_{min} + 1\}$$

where B_{sect} denotes the number of bytes of the information signals recorded in one sector of the recording medium, S_{max} denotes the number of sectors included in an outermost circumferential track of the recording medium, and S_{min} denotes the number of sectors included in an innermost circumferential track of the recording medium.

4. Apparatus for recording and reproducing information signals (S3) of binary digital signal train using an information signal recording medium (15) formed with circular information signal tracks divided into a plurality of sectors having sector addresses, the apparatus comprising:

means (20) for generating a plurality of initial values according to the sector addresses;
means (30) for generating a scrambling signal based on each generated initial value;
means (40) for scrambling the information signals, and, in the case of reproduction, de-scrambling scrambled information signals read from said recording medium, in each sector with one of said scrambling signals each said scrambling signal being used for signals in a predetermined plurality of sequential sectors;
wherein a starting point of the scrambling signal used for the signals in each said predetermined plurality of sequential sectors is offset by a predetermined offset value from the starting point of the scrambling signal used for the signals in the immediately preceding predetermined plurality of sequential sectors, sectors in adjacent portions of said signal tracks being scrambled using different scrambling signals.

5. Apparatus for recording and reproducing information signals of binary digital signal train using an information signal recording medium formed with circular information signal tracks divided into a plurality of sectors having sector addresses, the apparatus comprising:

means for generating a first initial value based on the sector address, the first initial value being used over first sequential sectors of a predetermined number of sectors;
means for generating a second initial value based on the sector address, the second initial value being used over second sequential sectors of the predetermined number of sectors;
means for generating a first scrambling signal based on the first initial value;
means for generating a second scrambling signal based on the second initial value;
means for scrambling the information signals, and, in the case of reproduction, de-scrambling scrambled information signals read from said recording medium, per sector with repeated use of the first scrambling signal that starts at the first initial value with respect to each sector of the first sequential sectors and with repeated use of the second scrambling signal that starts at the second initial value with respect to each sector of the second sequential sectors,
wherein a starting point of the second scrambling signal corresponding to the second initial value is offset by a predetermined offset value from another starting point of the first scrambling signal corresponding to the first initial value.

6. A method of reproducing original information signals by de-scrambling scrambled information signals of binary digital signal train read from an information signal recording medium formed with circular information signal tracks

divided into a plurality of sectors having sector addresses, the scrambled information signals having been scrambled with scrambling signals having cyclic codes, the method comprising the steps of:

generating a plurality of initial values according to the sector addresses;
generating a scrambling signal based on each generated initial value; and
de-scrambling the scrambled information signals in each sector with one of said generated scrambling signals, each said scrambling signal being used to de-scramble a predetermined plurality of sequential sectors, wherein a starting point in said cyclic codes of the scrambling signal used to de-scramble the signals in each said predetermined plurality of sequential sectors is offset by a predetermined offset value from the starting point of the scrambling signal used to de-scramble the signals in the immediately preceding predetermined plurality of sequential sectors, sectors in adjacent portions of said signal tracks having been scrambled using different scrambling signals.

7. A method of reproducing original information signals by de-scrambling scrambled information signals of binary digital signal train read from an information signal recording medium formed with circular information signal tracks divided into a plurality of sectors having sector addresses, the scrambled information signals having been scrambled with scrambling signals having cyclic codes, the method comprising the steps of:

generating a first initial value based on the sector address, the first initial value being used over first sequential sectors of a predetermined number of sectors;
generating a second initial value based on the sector address, the second initial value being used over second sequential sectors of the predetermined number of sectors;
generating a first scrambling signal based on the first initial value;
generating a second scrambling signal based on the second value; and
de-scrambling the scrambled information signals per sector with repeated use of the first scrambling signal that starts at the first initial value with respect to each sector of the first sequential sectors and with repeated use of the second scrambling signal that starts at the second initial value with respect to each sector of the second sequential sectors,
wherein a starting point of the second scrambling signal corresponding to the second initial value is offset by a predetermined offset value from another starting point of the first scrambling signal corresponding to the first initial value.

8. The method of reproducing original information signals of Claim 6 or 7, wherein the scrambled information signals are de-scrambled by obtaining exclusive OR of the scrambled information signals and the cyclic codes composed of $(2^x - 1)$ units of binary numbers;

and further a degree x of the cyclic codes is determined as follows:

$$x > \log_2 \{8 \times B_{sect} \times (1 + S_{max} / S_{min}) + 1\}$$

where B_{sect} denotes the number of bytes of the information signals recorded in one sector of the recording medium, S_{max} denotes the number of sectors included in an outermost circumferential track of the recording medium, and S_{min} denotes the number of sectors included in an innermost circumferential track of the recording medium.

9. Apparatus for reproducing original information signals by de-scrambling scrambled information signals (S3) of binary digital signal train read from an information signal recording medium (15) formed with circular information signal tracks divided into a plurality of sectors having sector addresses, the apparatus comprising:

means for generating a plurality of initial values according to the sector addresses;
means for generating a scrambling signal based on each generated initial value;
means for de-scrambling the scrambled information signals read from the recording medium in each sector with one of said scrambling signals each said scrambling signal being used to de-scramble signals in a predetermined plurality of sequential sectors;
wherein a starting point of the scrambling signal used to de-scramble the signals in each said predetermined plurality of sequential sectors is offset by a predetermined offset value from the starting point of the scrambling signal used to de-scramble the signals in the immediately preceding predetermined plurality of sequential sectors, sectors in adjacent portions of said signal tracks having been scrambled using different scrambling sig-

nals.

10. Apparatus for reproducing original information signals by de-scrambling scrambled information signals of binary digital signal train read from an information signal recording medium formed with circular information signal tracks divided into a plurality of sectors having sector addresses, the apparatus comprising:

means for generating a first initial value based on the sector address, the first initial value being used over first sequential sectors of a predetermined number of sectors;
means for generating a second initial value based on the sector address, the second initial value being used over second sequential sectors of the predetermined number of sectors;
means for generating a first scrambling signal based on the first initial value;
means for generating a second scrambling signal based on the second initial value;
means for de-scrambling the information signals per sector with repeated use of the first scrambling signal that starts at the first initial value with respect to each sector of the first sequential sectors and with repeated use of the second scrambling signal that starts at the second initial value with respect to each sector of the second sequential sectors,
wherein a starting point of the second scrambling signal corresponding to the second initial value is offset by a predetermined offset value from another starting point of the first scrambling signal corresponding to the first initial value.

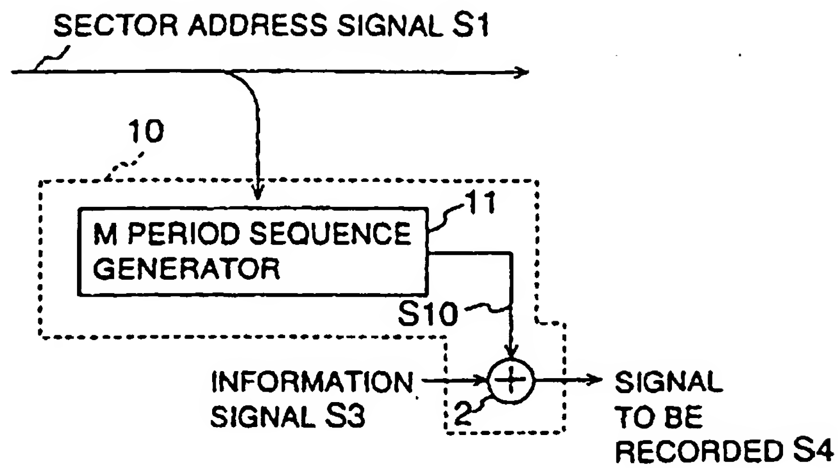
SECTOR ADDRESS SIGNAL S1
10
M PERIOD SEQUENCE GENERATOR
11
S10
INFORMATION SIGNAL S3
2
SIGNAL TO BE RECORDED S4

FIG.1

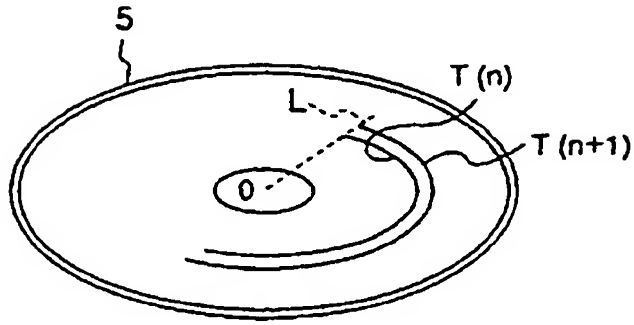

FIG.2A

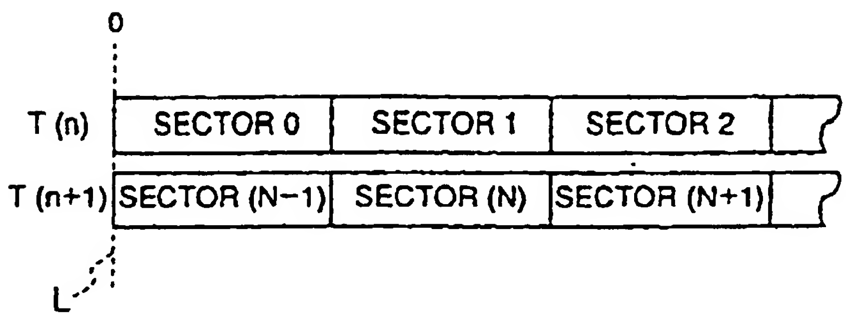

FIG.2B

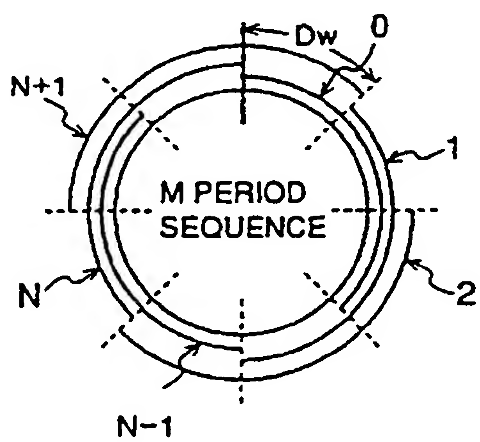

FIG.2C

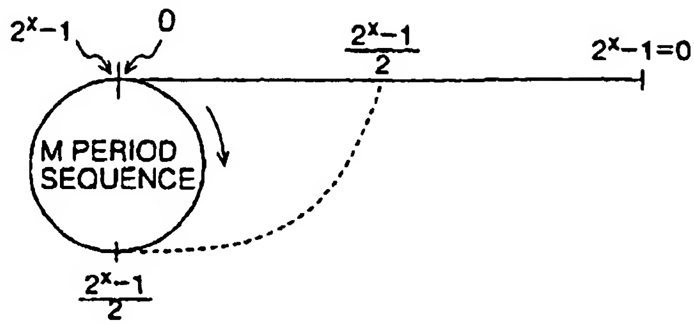
2^x-1
0
$\frac{2^x-1}{2}$
$2^x-1=0$
M PERIOD SEQUENCE
$\frac{2^x-1}{2}$

FIG.3A

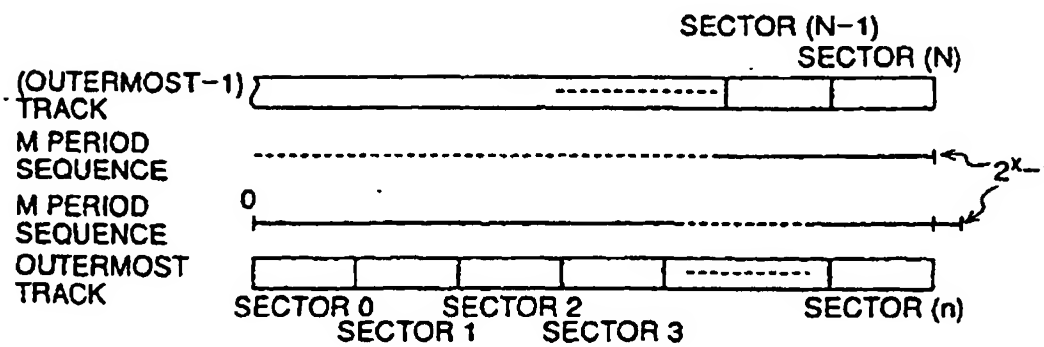
SECTOR (N-1)
SECTOR (N)
(OUTERMOST-1) TRACK
M PERIOD SEQUENCE
2^x-1
M PERIOD SEQUENCE
0
OUTERMOST TRACK
SECTOR 0
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR (n)

FIG.3B

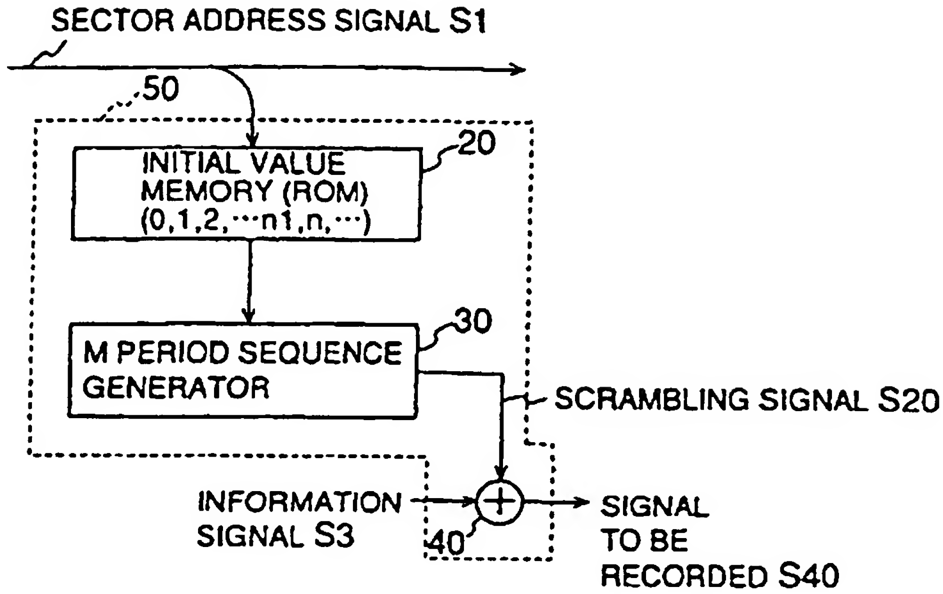
SECTOR ADDRESS SIGNAL S1
50
INITIAL VALUE MEMORY (ROM) (0,1,2,···n1,n,···)
20
M PERIOD SEQUENCE GENERATOR
30
SCRAMBLING SIGNAL S20
INFORMATION SIGNAL S3
40
SIGNAL TO BE RECORDED S40

FIG.4A

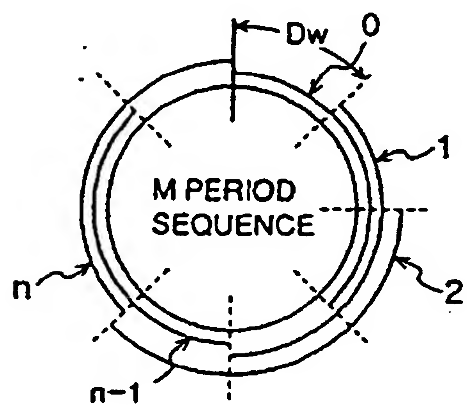
Dw
0
1
M PERIOD SEQUENCE
2
n
n−1

FIG.4B

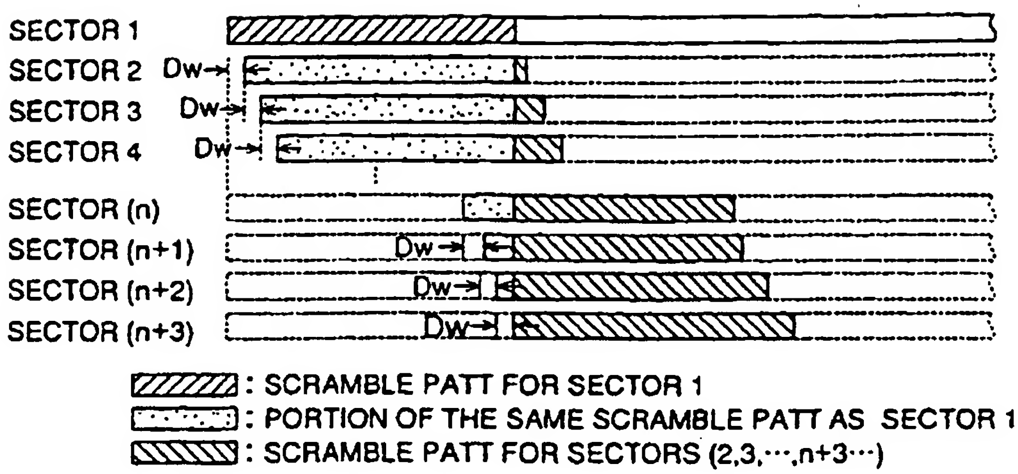
SECTOR 1
SECTOR 2
SECTOR 3
SECTOR 4
SECTOR (n)
SECTOR (n+1)
SECTOR (n+2)
SECTOR (n+3)
Dw
: SCRAMBLE PATT FOR SECTOR 1
: PORTION OF THE SAME SCRAMBLE PATT AS SECTOR 1
: SCRAMBLE PATT FOR SECTORS (2,3,···,n+3···)

FIG.5A

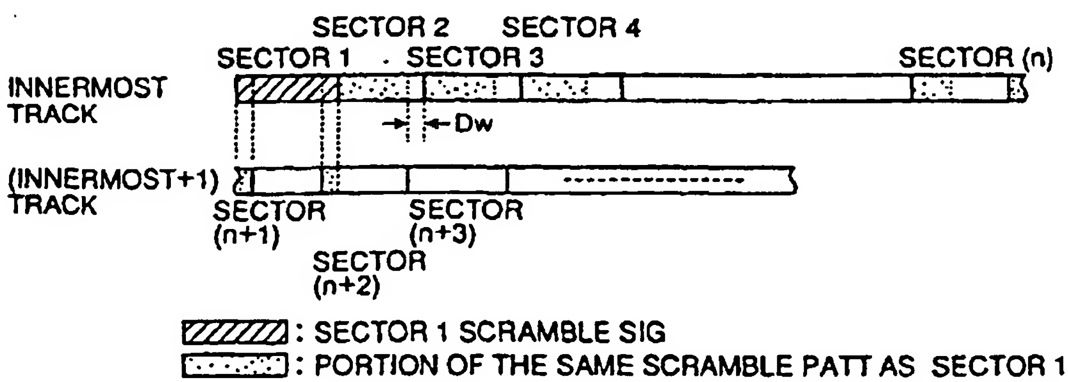
SECTOR 2
SECTOR 4
SECTOR 1
SECTOR 3
SECTOR (n)
INNERMOST TRACK
Dw
(INNERMOST+1) TRACK
SECTOR (n+1)
SECTOR (n+3)
SECTOR (n+2)
: SECTOR 1 SCRAMBLE SIG
: PORTION OF THE SAME SCRAMBLE PATT AS SECTOR 1

FIG.5B

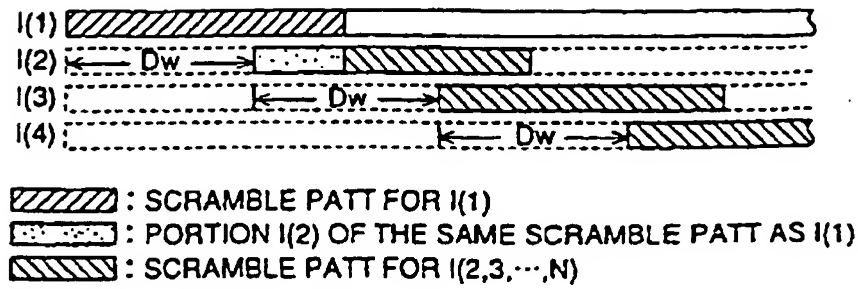

FIG.6A

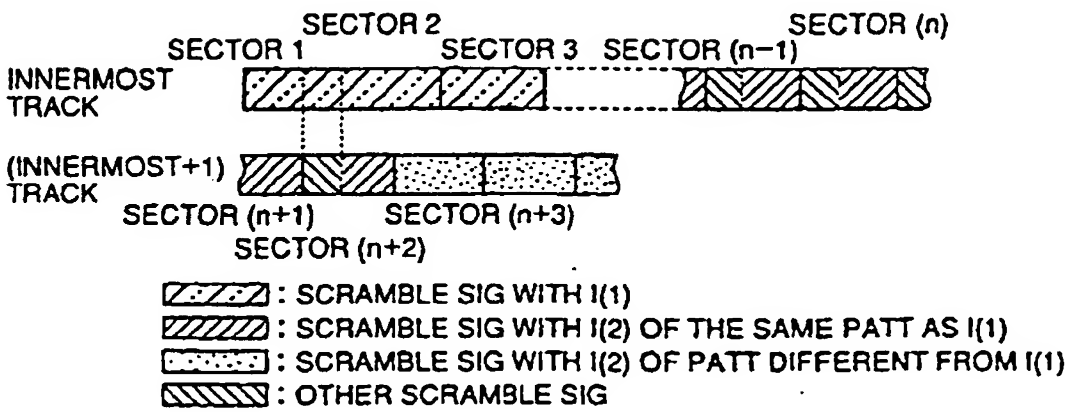

FIG.6B

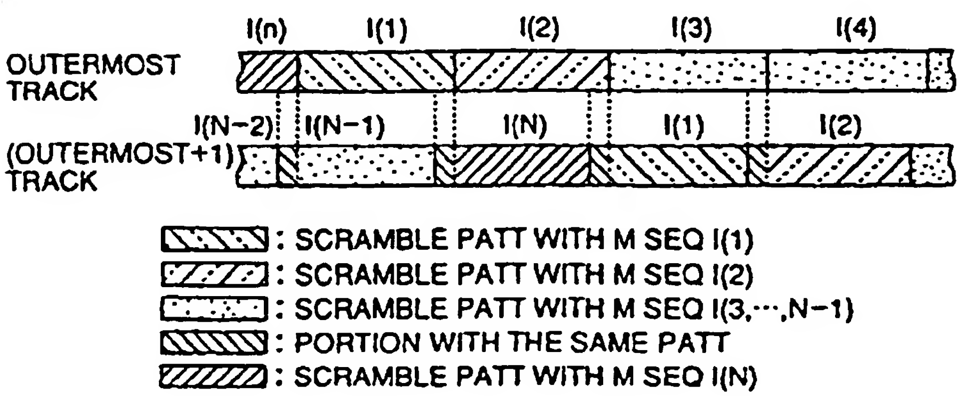

FIG.6C